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(51) INT CL[7]
H05H 1/28

(52) UK CL (Edition S)
H5H HND H2A1 H2A2B

(56) Documents Cited
GB 1507336 A **GB 0911538 A** **WO 09/10366 A1**
US 3769441 A

(58) Field of Search
UK CL (Edition R) **H5H HND**
INT CL[7] **H05B 7/12 , H05H 1/28**
ONLINE:JAPIO, EPODOC, WPI

(54) Abstract Title
Plasma torch electrode

(57) A flow of coolant is provided along the axis of the torch towards to the electrode tip 19, radially outwards across the rear surface of the electrode tip 19 and axially away from the electrode tip. Elongate orifices 17, 17' and 26, 26' are provided to facilitate flow. The orifices 26; 26'' may be inclined in the direction of flow to further reduce the flow restrictions.

FIG. 1.

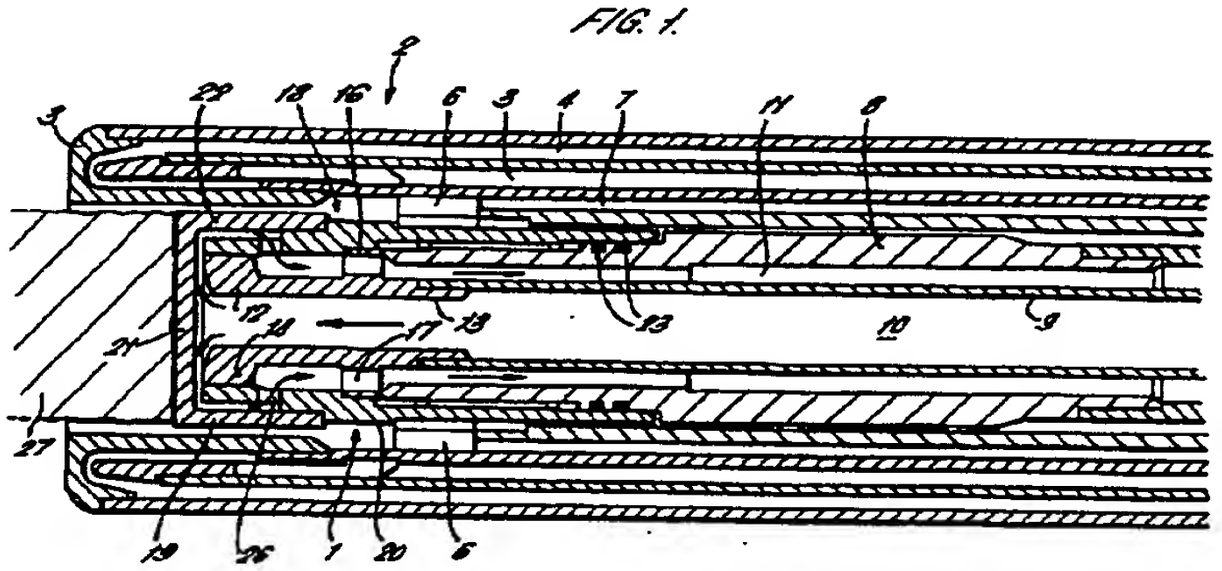


FIG. 4A.

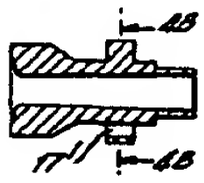


FIG. 4B.

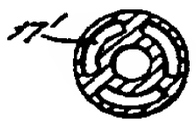


FIG. 5A.

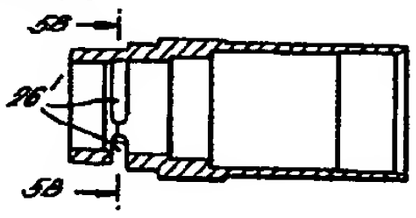


FIG. 5B.

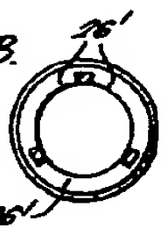
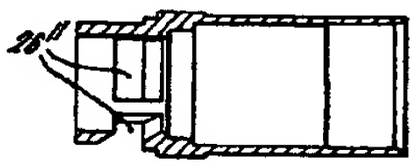


FIG. 6.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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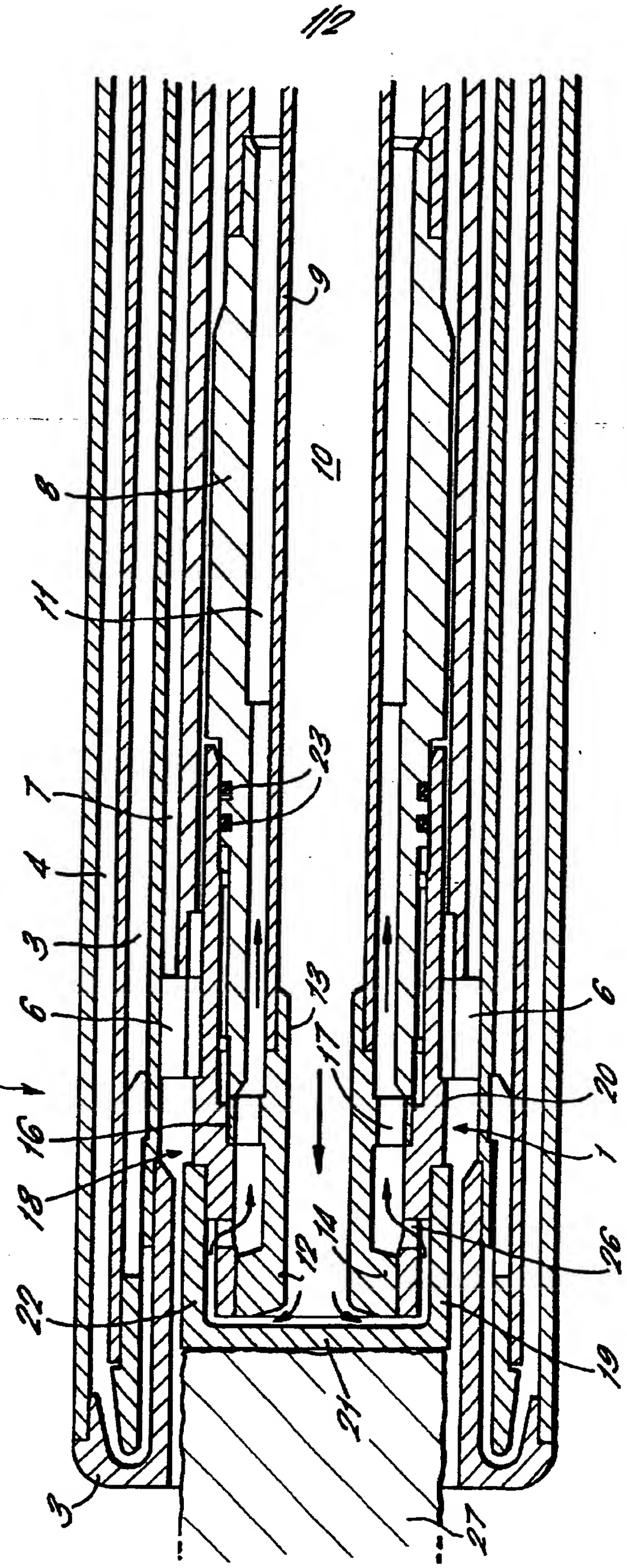


FIG. 1.

FIG. 2A.

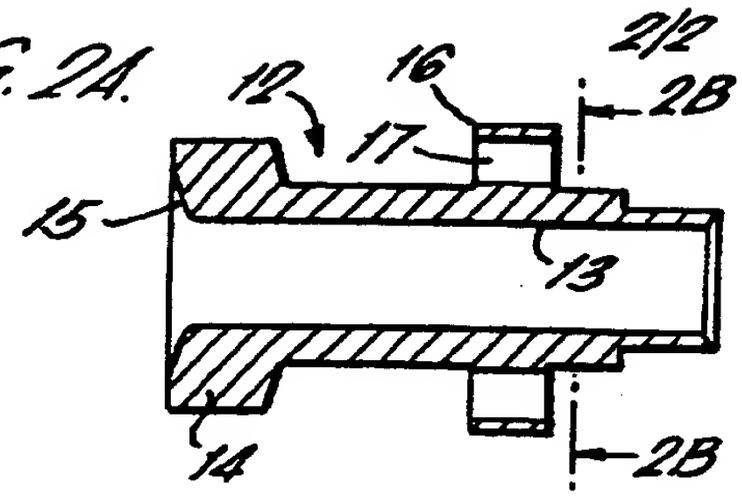


FIG. 2B.

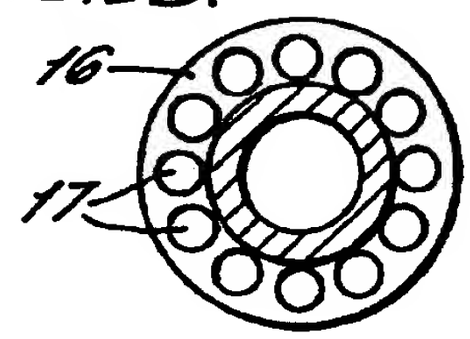


FIG. 3A.

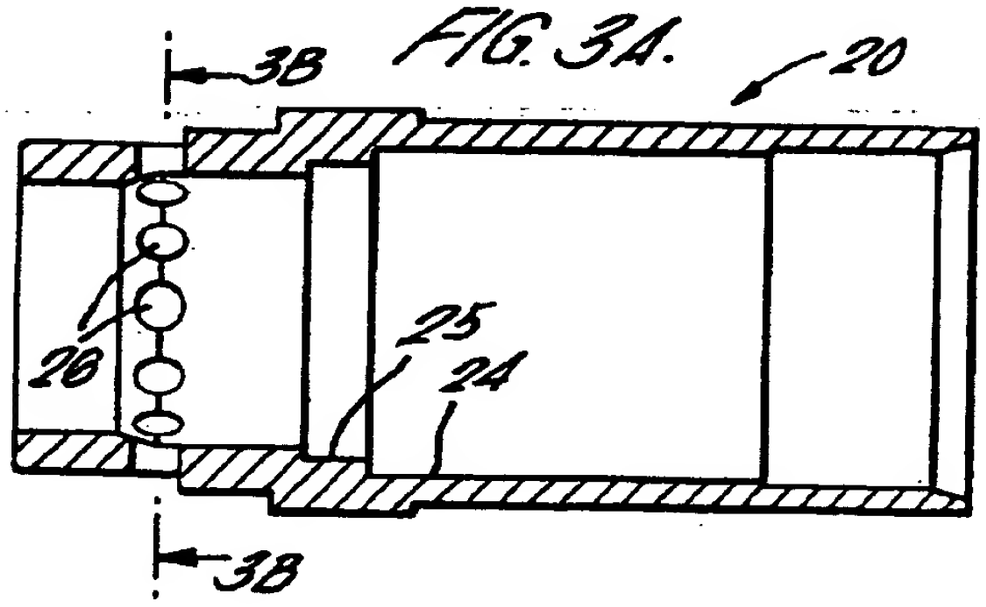


FIG. 3B.

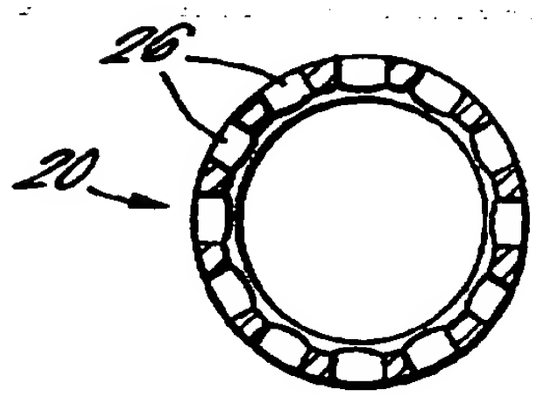


FIG. 4A.

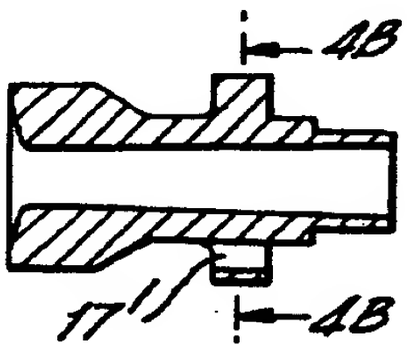


FIG. 4B.

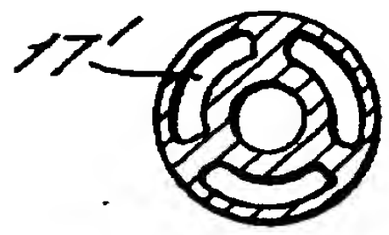


FIG. 5A.

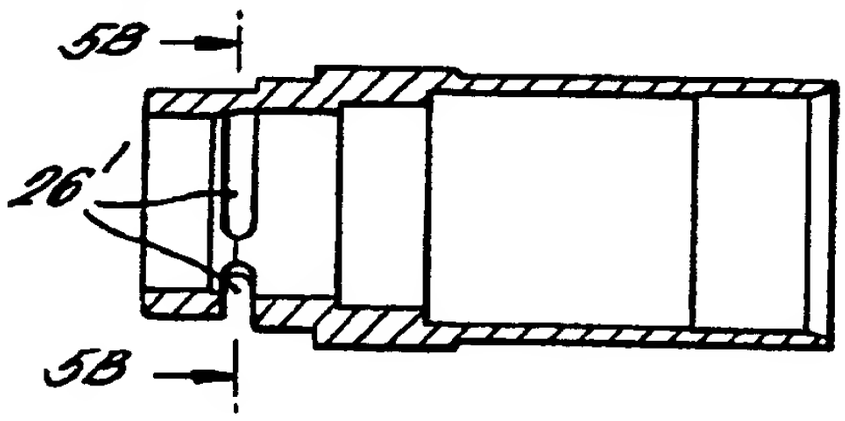


FIG. 5B.

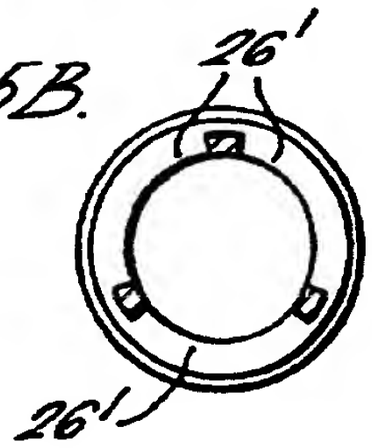
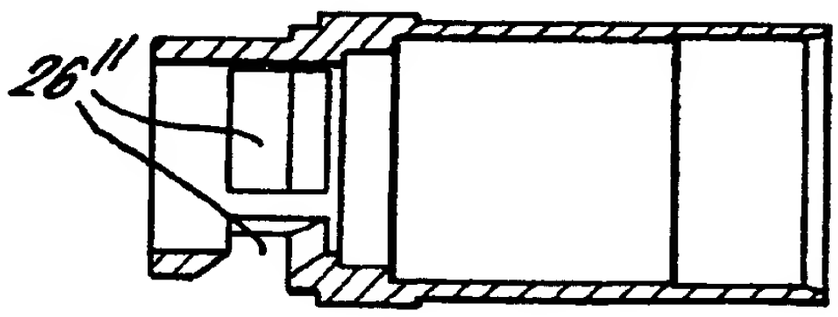


FIG. 6.



AN ELECTRODE FOR A PLASMA TORCH

This invention relates to an electrode for a plasma torch. Such torches are widely known in the art for carrying out operations such as heating, melting, welding and cutting.

A well known design is illustrated in Figures 1 to 3. A torch to this design is manufactured by the applicant as the 70mm Anode Torch.

Figure 1 shows a cross-section of the end of the torch at which plasma is generated (which will be referred to subsequently as the distal end). The torch broadly comprises an electrode assembly 1 which in this case is an anode surrounded by a nozzle 2 which projects beyond the distal end of the electrode assembly 1. The nozzle 2 is provided with a pair of coaxial coolant parts which carry coolant to and from the distal end of the torch. An annular copper brace 5 closes off the end of the two coolant paths 3,4 and provides an electrically conductive shroud surrounding and extending beyond the electrode assembly 1.

The electrode assembly 1 is retained within the nozzle 5 and is held in place by a ring of spacers 6 disposed around the electrode assembly 1. These spacers are made of an electrically insulating material to insulate the electrode assembly 1 from the nozzle 2. The gap between the electrode assembly 1 and nozzle 2 provided by the spacers 6 provides an annular flow path 7 for the flow of ionisable gas around the tip of the electrode assembly 1 and out of the distal end of the torch.

The electrode assembly 1 is mounted on a pair of coaxial tubular members, namely an outer tubular

member 8 and inner tubular member 9. The inner tubular member 9 defines an inner coolant passage 10 extending axially along the centre of the electrode assembly 1 so as to convey liquid coolant axially towards the tip of the electrode. The annular gap between the inner 9 and outer 8 tubular members defines an outer coolant passage 11 for the returning flow of liquid coolant which has absorbed heat at the electrode tip. Fixed in place at the end of the inner tubular member 9 is a flow divider 12 as shown in Figures 2A and 2B. This is an essentially tubular device having an internal bore 13 which is a continuation of the inner coolant passage 10. At its distal end, the thickness of the wall increases to provide a radially enlarged end 14. The distal end wall 15 of the flow divider 12 has a shallow taper to facilitate the flow of coolant around the radially enlarged end 14.

As best shown in Figures 2A and 2B, an annular flange 16 surrounds the body of the flow divider 12 and is spaced from the distal end of the flow divider 12. The annular flange 16 is provided with a circumferential array of circular through holes 17 for reasons to be described below.

An electrode tip assembly comprises an electrode tip 19 and an electrode tip holder 20. The electrode tip 19 is a cap shaped member having a circular top 21 from which a peripheral skirt 22 depends. The tip holder 20 is inserted into and brazed to the tip 19 to form a unitary component.

The proximal end of the tip holder 20 fits over the end of the outer tubular member 8 and is sealed by a pair of O-rings 23. The tip holder 20 has a tubular construction as shown in Figures 3A and 3B so as to

receive the flow divider 12 as shown in Figure 1. The internal bore 24 of the tip holder 20 has a radially inwardly stepped portion 25 providing a shoulder on which the flange 16 of the flow divider 12 locates. The distal ends of the tip holder 20 has smaller internal and external diameters than the rest of the tip holder. The internal diameter is dimensioned so that the radially enlarged end 14 of the flow divider 12 fits tightly within and seals with the end of the tip holder. A circumferentially arranged array of circular through holes 26 are provided around the tip holder 20. The holes are spaced from the distal end of the tip holder 20 to a sufficient extent that, when the flow divider 12 is inserted to its full extent into the tip holder, the enlarged head 14 of the tip holder 12 will have passed axially beyond the holes 26 allowing coolant to enter the tip holder 20 through the holes 26.

Although the illustrated electrode is an anode, the present invention is equally applicable to a cathode. This has the same structure in most respects as the anode, except that a tapering lump of conductive material is provided on the outer surface of the electrode tip.

In operation, with an ionisable gas flowing through the passage 7, an arc is initially struck-up between the top 21 of the electrode tip 19 and the copper brace 5 of the nozzle 2. This arc is then quickly transferred to exist between the workpiece and the top 21 of the electrode assembly 1 with the end of the nozzle 2 simply acting as a shroud for the gas. A plasma is established in the region 27 downstream of the electrode tip 19. This operation generates significant amounts of heat at the radially innermost part of the distal end of the copper brace, which is

cooled by coolant flowing in the passages 3,4. Significant heat is also generated at the top 21 of the electrode tip. Liquid coolant flows along the inner coolant passage 10, across the rear face of the top 21 of electrode tip 19, into the tip holder 20 via holes 26, and along the outer coolant passage 11 via holes 17.

The present invention addresses the problem of how to improve the cooling of the electrode tip.

There is an ever increasing demand for plasma torches which can provide higher heating rates. In order to do this, the current carrying capacity of the torch has to be increased. Further, in lower current applications, there is a need to prolong the life of the torch to reduce electrode replacement costs and improve operational reliability. As current levels increase, the amount of heat generated in the electrode correspondingly increases. The maximum current which can be supplied to the electrode is therefore determined by the efficiency of the cooling at the electrode tip. The heat flux densities on the electrode are already extremely high (up to and in excess of 70MW/m^2).

One way of increasing the cooling of the electrode is to increase the speed of the coolant flow. However, faster water flows in the heat critical areas of the electrode will increase the local pressure drops in those areas. In order to compensate for this, the coolant pumping capacity can be increased. However, the ultimate pressure of the water cooling systems is limited by the ratings of a components of the cooling circuit, such as fittings, pipework, instrumentation and couplings.

A second way of achieving higher current capacity is to increase the size of the electrode as this reduces the heat flux density. Although this is effective with smaller lower power electrodes, it is of little benefit for larger diameter electrodes. As the diameter of the electrode increases the critical current density at which overheating occurs decreases so that the ultimate capacity remains almost unchanged.

The present invention takes a different approach to this problem in order to improve the cooling efficiency of the electrode tip, and hence increase the maximum current carrying capacity of the electrode.

According to a first aspect of the present invention there is provided an electrode for a plasma torch, the electrode having an axially elongate body with an electrically conductive tip at a distal end for arc generation at an outer surface of the tip, the electrode having a coolant circuit comprising a first duct extending along the axial centre of the electrode, a second duct extending axially and surrounding the first duct, a flow path adjacent to an inner surface of the tip connecting the first and second ducts, and an annular flange spaced from the electrode tip projecting radially outwardly from the first duct to support the second duct, the flange having a plurality of through holes for the flow of coolant, the circumferential dimension about the electrode axis of each through hole being greater than its radial dimension with respect to the electrode axis.

The inventors have recognised that although it is not practical to redesign the structure of the coolant

passage in the heat-critical areas of the electrode, significant improvements to the cooling efficiency can be obtained by reducing the flow restrictions, and hence the pressure drops, in parts of the coolant circuit which are non heat-critical. In this case, the replacement of the circular holes of the prior art with elongate slits not only increases the overall flow area of the passages, but also serves to reduce the throttling effects associated with smaller orifices.

The exact dimensions of the slots are configured to provide the maximum possible channel area for the flow while still maintaining the structural integrity of the electrode. Preferably, however, the circumferential dimension of each through hole is at least twice, more preferably at least three times, and most preferably at least four times its radial dimension. The circumferential dimension is the length of the arc from one end of the through hole to the other.

According to a second aspect of the present invention, there is provided an electrode for a plasma torch, the electrode having an axially elongate body with an electrically conductive tip at a distal end for arc generation at an outer surface of the tip, the electrode having a coolant circuit comprising a first duct extending along the axial centre of the electrode, a second duct extending axially and surrounding the first duct, and a flow path adjacent to an inner surface of the tip connecting the first and second ducts, the end of the second duct surrounding and sealing with the end of the first duct adjacent to the tip, the second duct being provided with a plurality of through holes to allow the coolant to enter the second duct, the circumferential

dimension about the electrode axis of each through hole being greater than its dimension in the direction of the electrode axis.

The inventors have recognised that although it is not practical to redesign the structure of the coolant passage in the heat-critical areas of the electrode, significant improvements to the cooling efficiency can be obtained by reducing the flow restrictions, and hence the pressure drops, in parts of the coolant circuit which are non heat-critical. In this case, the replacement of the circular holes of the prior art with elongate slits not only increases the overall flow area of the passages, but also serves to reduce the throttling effects associated with smaller orifices.

The exact dimensions of the slots are configured to provide the maximum possible channel area for the flow while still maintaining the structural integrity of the electrode. Preferably, however, the circumferential dimension of each through hole is at least twice, more preferably at least three times, and most preferably at least four times its axial dimension. The circumferential dimension is the length of the arc from one end of the through hole to the other.

According to a third aspect of the present invention, there is provided an electrode for a plasma torch, the electrode having an axially elongate body with an electrically conductive tip at a distal end for arc generation at an outer surface of the tip, the electrode having a coolant circuit comprising a first duct extending along the axial centre of the electrode, a second duct extending axially and surrounding the first duct, and a flow path adjacent

to an inner surface of the tip connecting the first and second ducts, the end of the second duct surrounding and sealing with the end of the first duct adjacent to the tip, the second duct being provided with a plurality of through holes to allow the coolant to enter the second duct, each through hole being inclined radially inwardly away from the distal end of the electrode.

This aspect of the invention is also based on reducing the pressure drop in non heat-critical areas of the water cooling system. However, this aspect of the invention achieves the same result not by increasing the surface area of the flow, but instead by angling the through holes in the second duct so as to smooth the flow through these through holes.

Preferably, the circumferential dimension about the electrode axis of each through hole is greater than its dimension in the direction of the electrode axis. This serves to improve further the flow through the angled through holes.

The three aspects of the invention may be used individually, or together in any permutation.

Examples of electrodes constructed in accordance with the present invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a cross-section through an end of a plasma torch in accordance with the prior art;

Figure 2A shows the flow divider of Figure 1;

Figure 2B is a cross-section through line 2B-2B of Figure 2A;

Figure 3A shows the electrode tip holder of Figure 1;

Figure 3B is a cross-section through line 3B-3B of Figure 3A;

Figure 4A is a view is similar to Figure 2A showing a flow divider for an electrode in accordance with a first aspect of the present invention;

Figure 4B is a cross-section through line 4B-4B of Figure 4A;

Figure 5 is a view similar to Figure 3A showing an electrode tip holder for an electrode in accordance with a second aspect of the present invention;

Figure 5B is a cross-section through line 5B-5B of Figure 5A; and

Figure 6 is a view similar to Figures 3A and 5A showing an electrode tip holder for an electrode in accordance with a third aspect of the present invention.

The overall construction of the plasma torch in accordance with the present invention is the same in most respects as the prior art torch described in Figures 1 to 3. Detailed description of this torch will not therefore be repeated here. Instead, only the differences provided by the three aspects of the invention will be referred to.

The first aspect of the present invention is shown in Figures 4A and 4B. In this case, the circular through holes 17 of the prior art have been replaced by three circumferential elongate slots 17' arranged symmetrically about the axis of the flow divider. The

number and size of the slots 17' can be varied. However, from a comparison of Figures 2B and 4B, it will be appreciated that this arrangement of Figure 4B provides a considerable improvement in the overall cross-sectional area through the which coolant flows. Further, the flow restrictions caused by the relatively small size of the circular through holes will be greatly reduced with the elongate slots 17'.

The second aspect of the present invention is shown in Figures 5A and 5B. In this case, the plurality of circular through holes 26 have been replaced by three elongate slots 26' symmetrically disposed about the axis of the electrode tip holder. The number and size of the slots 26' can be varied. However, it will be appreciated from a comparison of Figures 3A, 3B, 5A and 5B that the overall flow area through the slots 26' is considerably greater than through the circular through holes 26, and that the flow restrictions through the slots 26' are now considerably less than through the circular through holes 26.

The third aspect of the invention is shown in Figure 6. The electrode tip holder is a modification of that shown in Figures 5A and 5B, in that the circumferential slots 26' are angled radially inwardly away from the distal end of the electrode. From a consideration of Figure 6 alongside Figure 1, it will be appreciated that the slanted slots will provide a significantly smoother passage for coolant into the electrode tip holder.

CLAIMS

1. An electrode for a plasma torch, the electrode having an axially elongate body with an electrically conductive tip at a distal end for arc generation at an outer surface of the tip, the electrode having a coolant circuit comprising a first duct extending along the axial centre of the electrode, a second duct extending axially and surrounding the first duct, a flow path adjacent to an inner surface of the tip connecting the first and second ducts, and an annular flange spaced from the electrode tip projecting radially outwardly from the first duct to support the second duct, the flange having a plurality of through holes for the flow of coolant, the circumferential dimension about the electrode axis of each through hole being greater than its radial dimension with respect to the electrode axis.

2. An electrode according to claim 1, wherein the circumferential dimension of each through hole is at least twice its radial dimension.

3. An electrode according to claim 2, wherein the circumferential dimension of each through hole is at least three times is radial dimension.

4. An electrode according to claim 3, wherein the circumferential dimension of each through hole is at least four times is radial dimension.

5. A plasma torch having an electrode according to any one of the preceding claims.

6. An electrode for a plasma torch, the electrode having an axially elongate body with an electrically conductive tip at a distal end for arc generation at

an outer surface of the tip, the electrode having a coolant circuit comprising a first duct extending along the axial centre of the electrode, a second duct extending axially and surrounding the first duct, and a flow path adjacent to an inner surface of the tip connecting the first and second ducts, the end of the second duct surrounding and sealing with the end of the first duct adjacent to the tip, the second duct being provided with a plurality of through holes to allow the coolant to enter the second duct, the circumferential dimension about the electrode axis of each through hole being greater than its dimension in the direction of the electrode axis.

7. An electrode according to claim 6, wherein the circumferential dimension of each through hole is at least twice its axial dimension.

8. An electrode according to claim 7, wherein the circumferential dimension of each through hole is at least three its axial dimension.

9. An electrode according to claim 8, wherein the circumferential dimension of each through hole is at least four its axial dimension.

10. A plasma torch having an electrode according to any of claims 6 to 9.

11. an electrode for a plasma torch, the electrode having an axially elongate body with an electrically conductive tip at a distal end for arc generation at an outer surface of the tip, the electrode having a coolant circuit comprising a first duct extending along the axial centre of the electrode, a second duct extending axially and surrounding the first duct, and a flow path adjacent to an inner surface of the tip

connecting the first and second ducts, the end of the second duct surrounding and sealing with the end of the first duct adjacent to the tip, the second duct being provided with a plurality of through holes to allow the coolant to enter the second duct, each through hole being inclined radially inwardly away from the distal end of the electrode.

12. An electrode according to 11, wherein the circumferential dimension about the electrode axis of each through hole is greater than its axial dimension in the direction of the electrode axis.

13. A plasma torch having an electrode according to claim 11 or claim 12.

The Patent Office

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14.

Application No: GB 9924174.7 **Examiner:** John Cockitt
Claims searched: 1-5 **Date of search:** 20 April 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): H5H [HND]

Int Cl (Ed.7): H05H [1/28]; H05B [7/12]

Other: ONLINE: EPODOC, WPI, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	GB1507336A INSTITUT	
A	WO90/10366A1 TETRONICS	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

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15.

Application No:	GB 9924174.7	**Examiner:**	John Cockitt
Claims searched:	6-10	**Date of search:**	30 November 2000

Patents Act 1977
Further Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): H5H [HND]

Int Cl (Ed.7): H05H [1/28]; H05B [7/12]

Other: ONLINE: EPODOC, WPI, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	GB0911538A FOSTER	
A	US3769441A SCHLIENGER	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

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16.

Application No: GB 9924174.7 **Examiner:** John Cockitt
Claims searched: 11-13 **Date of search:** 30 November 2000

Patents Act 1977
Further Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): H5H [HND]

Int Cl (Ed.7): H05H [1/28]; H05B [7/12]

Other: ONLINE: EPODOC, WPI, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	US3769441A	SCHLIENGER - radially inwardly directed passage portions	11 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.